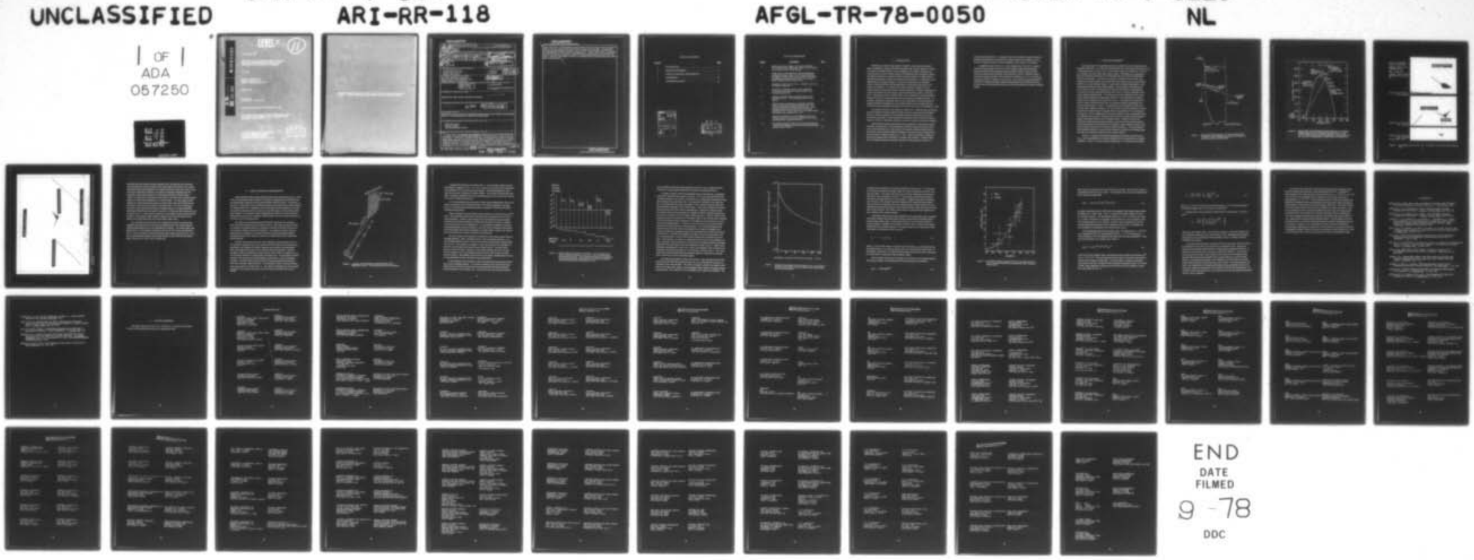
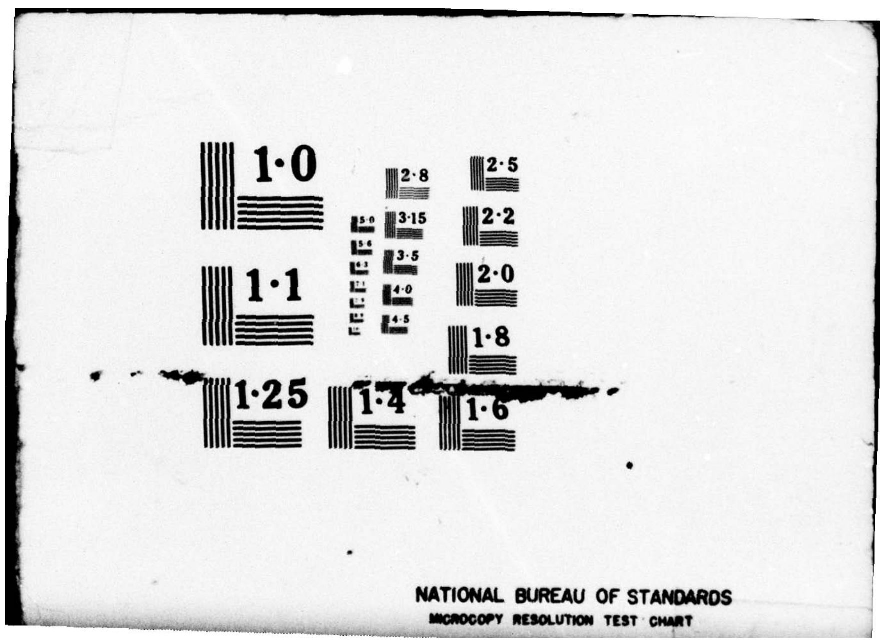
AD-A057 250   AERODYNE RESEARCH INC BEDFORD MASS   F/G 4/1
ANALYSIS OF ELECTRON RETARDING POTENTIAL ANALYZER MEASUREMENTS --ETC(U)
JAN 78 F BIEN   F19628-76-C-0229
UNCLASSIFIED   ARI-RR-118   AFGL-TR-78-0050   NL

1 OF 1
ADA
057250



END
DATE
FILMED
9-78
DDC


1·0
2·8
2·5
3·15
2·2
3·5
1·1
2·0
4·0
4·5
1·8
1·25
1·4
1·6
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

AFGL-TR-78-0050

ANNALYSIS OF ELECTRON RETARDING POTENTIAL ANALYZER MEASUREMENTS OF VEHICLE SKIN POTENTIAL IN THE PRECEDE EXPERIMENT

Fritz Bien

Aerodyne Research, Inc.
Bedford Research Park
Bedford, Massachusetts 01730

January 1978

Final Report
January 1977 - January 1978

This research was sponsored by the Defense Nuclear Agency under Subtask L25AAXHX632 entitled, "IR Phenomenology and Optical Code Data Base."

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

Qualified requestors may obtain additional copies from the Defense D

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE 18 19

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFGL-TR-78-0050
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): 6 ANALYSIS OF ELECTRON RETARDING POTENTIAL ANALYZER MEASUREMENTS OF VEHICLE SKIN POTENTIAL IN THE PRECEDE EXPERIMENT.
5. TYPE OF REPORT & PERIOD COVERED: 9 Final Report, Jan[redacted]977-Jan[redacted]978
6. PERFORMING ORG. REPORT NUMBER: 14 ARI-RR-118
7. AUTHOR(s): 10 Fritz Bien
8. CONTRACT OR GRANT NUMBER(s): 15 F19628-76-C-0229
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Aerodyne Research, Inc. Bedford Research Park Bedford, MA 01730
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: CDNA-00 76701006 17 10,00
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Geophysics Laboratory Hanscom AFB, Massachusetts 01731 Monitor/Robert R. O'Neil/OPR
12. REPORT DATE: 11 Janu[redacted]1978
13. NUMBER OF PAGES: 49
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 28p.
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited

62101 F, 62704A

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report): 62707H 16 CDNA, 767

18. SUPPLEMENTARY NOTES: This research was sponsored by the Defense Nuclear Agency under Subtask L25AAXHX632 entitled, "IR Phenomenology and Optical Code Data Base."

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

EXCEDE Analysis
Vehicle charging
Retarding potential analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A 2 kW electron accelerator was launched in October 1974 from the White Sands Missile Range, New Mexico as the initial launch in the EXCEDE series of artificial auroral experiments. The launch, designated PRECEDE, was supported by a number of ground based optical systems to record the electron induced atmospheric emissions as a remote diagnostic technique of accelerator performance in addition to recording emissions of aeronomic interest in a controlled artificial aurora. The electron source, square wave modulated at 0.5 Hz, was initiated at 95 km on payload ascent and continued through

next page

390 172

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

78 08 03 30

apogee (120 km) to a decent altitude of approximately 80 km providing a total of 90 pulses of the 2.5kV 0.8 ampere electron beam over a period of 180 seconds. A rocketborne retarding potential analyzer provided a measure of the vehicle potential due to a net positive charge build up on the electron emitting payload. A steady-state vehicle potential of less than 30 volts was indicated at apogee with substantially smaller values at lower altitudes. Langmuir probe theory is shown to accurately model the altitude dependent steady-state vehicle potential.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

EXCEDE is an experimental program designed to study auroral processes using a rocketborne electron accelerator operating in the altitude range 80 to 140 km. The primary scientific interest is the investigation of the detailed production and loss processes of various excited electron and vibrational status resulting in optical and infrared emission as energetic primary electrons and their secondary and all subsequent generation electrons are stopped in the atmosphere. In artificial auroral experiments, the dosing conditions of: electron energy and power, deposition volume, deposition altitude and dosing duration are parameters that may be controlled and monitored. In natural aurora, these excitation conditions must be inferred and the observed atmospheric emissions typically are effects integrated over a range of conditions (electron energy, electron-flux density, altitude, and dosing time). Observations of these integral effects make interpretation of optical/infrared emissions in terms of basic production and loss processes excedingly complex. At present, considerable uncertainty exists in the interpretation of auroral optical and infrared emissions including such a well-studied feature as the auroral green line, $O(^1S)$ 5577A emission (Slanger and Black, 1973; Rees and Luckey, 1974; Shepherd, 1974).

The primary objective of the EXCEDE program is to: determine the mechanisms in which energetic electrons partition energy as they are stopped in the atmosphere, follow the chemical reactions of electron induced ionized and excited species and observed the ultraviolet, optical and infrared emissions induced directly by electron impact as well as the emissions induced by a series of consecutive chemical reactions.

Other artificial auroral experiments using rocketborne accelerators providing energetic electron beams of several kilowatts include the launch described by Hess et al. (1971) and Davis et al. (1971) and the more recent results reported from the joint Franco-Soviet ARAKS (Artificial Radiation and Auroras between Kergueten and the Soviet Union) Program (Çambou et al., 1975). These experiments, designed to study the geomagnetic field orientation, conjugate point locations, conjugate reflection of energetic electrons and particle drift rates, utilized apogees in excess of

several hundred kilometers. In contrast to these other artificial auroral studies the EXCEDE experiments are conducted in the denser atmosphere at altitudes of 80 to 120 km to confine the electron excited atmosphere to the vicinity of the payload.

A feasibility study (O'Neil et al., 1973) indicated that 3 kW (3 kV, 1 ampere) electron beams deposited in the 100 to 120 km altitude range provided selected optical and infrared time dependent radiance profiles readily measured by both rocket and ground based photometric and radiometric sensors. Specific infrared emissions of interest include electron induced NO radiation at 2.7 to 5.4 microns as well as CO_2 and NO^+ radiation at 4.3 microns. The present report summarizes the rocketborne retarding potential analyzer measurements of the PRECEDE launch and infers an altitude dependent steady state vehicle potential for the electron emitting vehicle.

2. PRECEDE EXPERIMENT

This initial launch in the EXCEDE program of artificial auroral experiments was designated PRECEDE. The PRECEDE launch vehicle was a Nike Hydac Rocket (EX 407.41-1) instrumented with a 2 kW (2.5 kV, 0.8A) electron accelerator launched at 10:20:00 UT on 17 October 1974 from White Sands Missile Range. This flight was an engineering test of the electron accelerator to be subsequently used on the heavily instrumented follow-on experiments. The electron accelerator consisted of three modules with separate high voltage supplies and tungsten filaments directly heated to approximately $2800^{o}K$ by a common filament supply. A square wave oscillator operating at 0.5 Hz synchronously pulsed the high voltage supplies. The accelerator high voltage supplies powered by silver cell batteries were each current limited to approximately 0.5 amperes to avoid catastrophic failure in the event of arcing or momentary short circuit operation during launch. The electron source was initiated at 95 km on payload ascent and continued through apogee (120 km) to a descent altitude of approximately 80 km, operating for an interval of 180 sec. The payload was launched from north to south so that the electron beam was deposited along the geomagnetic field above the payload (Figs. 1 and 2). The trajectory for the PRECEDE launch was in the plane of the magnetic declination, 12^{o} east, and the Tiff optical station was located to observe the payload along the magnetic field at approximately 100 km during payload descent. In this configuration the electron deposition volume, constrained along the magnetic field, presents a minimal source size for the photometric and spectrographic instruments located at the Tiff optical station. Stations at Denver and Cloudcroft contained various camera systems to record the electron-induced atmospheric luminescence with viewing aspects arranged to image radiance along the magnetic field and record the size of electron-excited atmosphere. On board measurements included monitors of electron-beam voltage and current and a retarding potential analyzer to determine particle flux and vehicle potential.

Figure 3, a montage of PRECEDE photographs from Denver optical site (see Fig. 1) is an illustration of the overall dimensions of the electron beam as a function of altitude. In Fig. 4 is given in greater spatial detail: the electron-beam energy

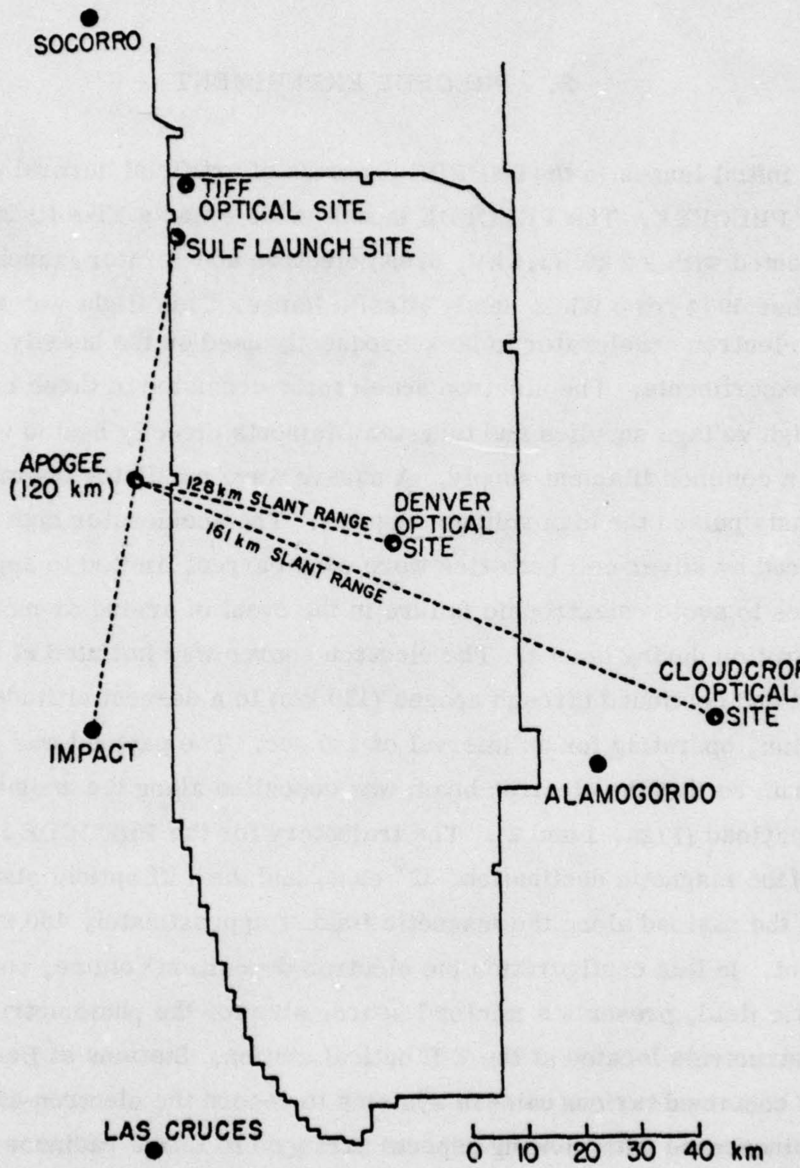


Figure 1. White Sands Missile Range, New Mexico Indicating the Trajectory of the PRECEDE Launch and the Location of the Three Optical Ground Stations.

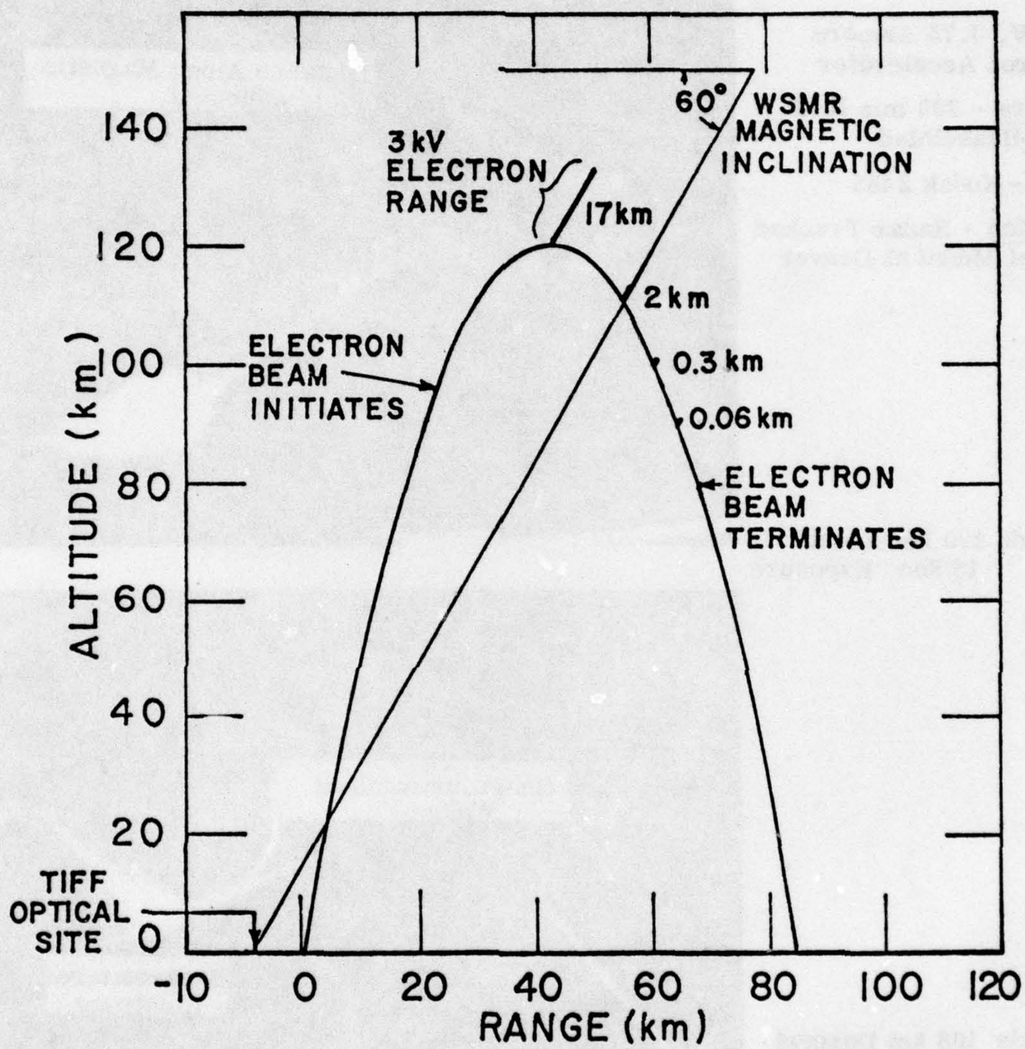


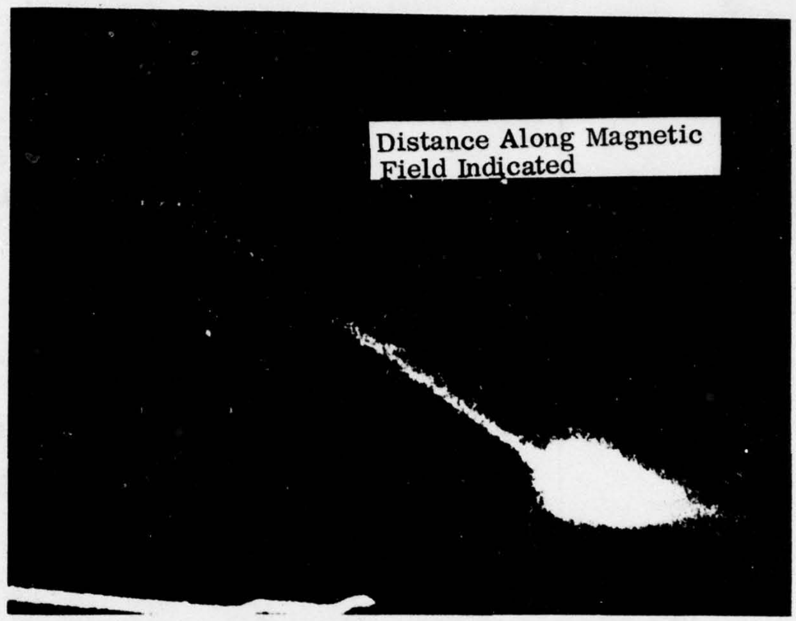
Figure 2. **Flight Profile of the PRECEDE Launch Indicating the Calculated Practical Range of a 3 kV Electron Along the Magnetic Field and the Viewing Aspect of the Image Intensified Spectrograph and the Two-Color Telephotometer Located at the Tiff Optical Site.**

2.5 kV, 0.75 Ampere
Electron Accelerator

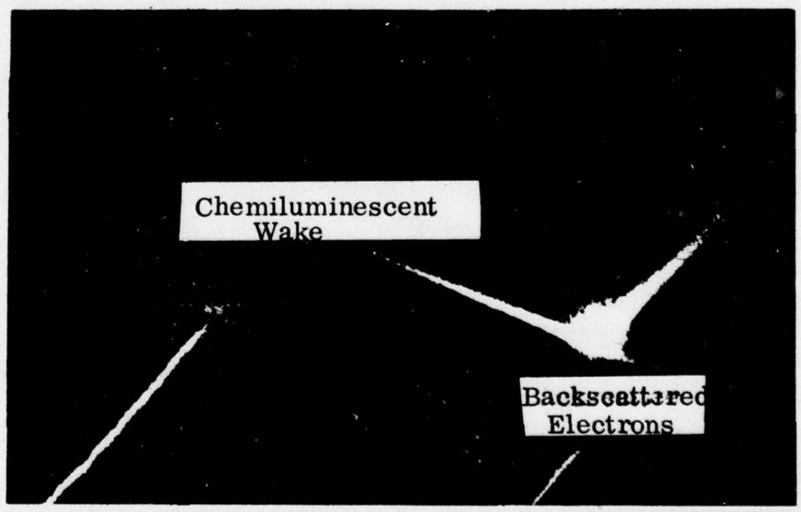
Camera - 300 mm f0.9
Delft-Hasselblad

Film - Kodak 2485

Location - Radar Tracked
Optical Mount at Denver
Site



Altitude 120 km Asent
16 Sec. Exposure



Altitude 108 km Descent
5 Sec. Exposure

Altitude 102 km Descent
2 Sec. Exposure
Beam Length 0.4 km

Figure 3. Photographs Taken By TIC, Inc., of Bedford, MA From the Denver Optical Site.

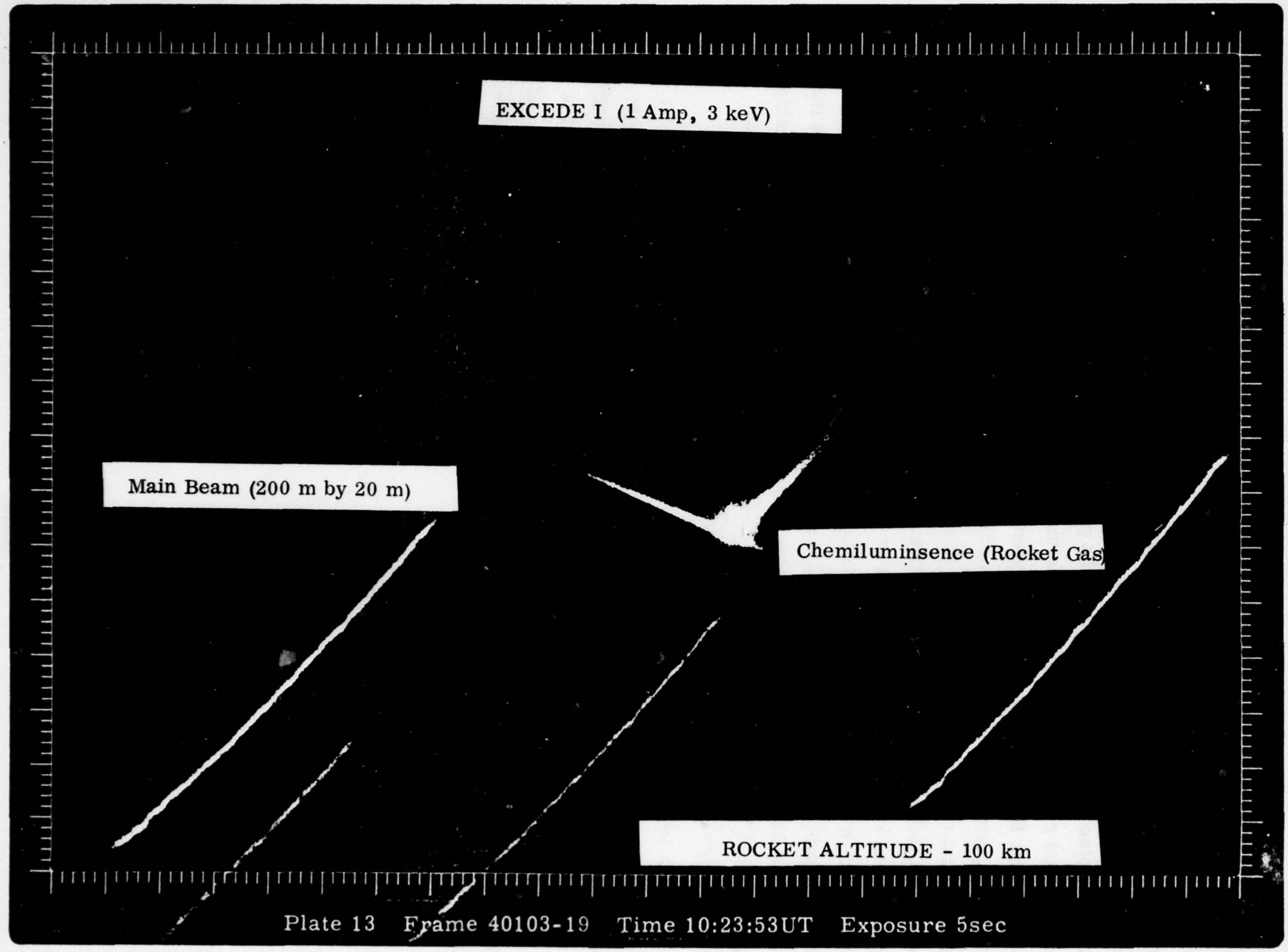


Figure 4. Atmospheric Emission Induced By the PRECEDE Accelerator Recorded By an Image Orithicon at the Cloudcroft Optical Site.

deposited above the payload along the magnetic field, the relatively faint electron-beam luminescence below the payload due to back-scattered electrons, and a bright chemiluminescent wake tangential to the payload trajectory believed to be due to residual rocket propellants (aluminum or aluminum compounds) outgassing from the smoldering Hydac rocket engine and reacting with atmospheric atomic oxygen. Figure 4, provided by the Cloudcroft optical station, was taken with an image orthicon system and represents an integration of several seconds. All three optical ground stations used radar controlled instrument mounts which located and tracked the payload within 1-arc min for the duration of the experiment. The precise tracking of the optical mounts allow the ground-based imaging systems, an image intensified spectrograph and the television and film cameras, to effectively utilize exposure times as long as 20 sec. For the spatial resolution of the imaging systems and the tracking precision of the optical mounts, effective exposure times were determined by the shutter-open period rather than by the focal-plane image smear.

The PRECEDE launch trajectory was configured such that the electron beam, originating from the nose of the payload, was deposited above the vehicle along the magnetic field without the use of an attitude control system. The nominal pitch angle ranged from 0 to 40° during the experiment and was 25° for the case represented in Fig. 4. The dimensions of electron range and radial scatter indicated in Fig. 3 and 4 are in good agreement with the experimental results of Grün (1957) and the calculations of Berger et al. (1970, 1974), respectively.

3. VEHICLE POTENTIAL MEASUREMENTS

Initial EXCEDE design studies included a theoretical estimate (Baum et al., 1975) of the time dependent vehicle potential of an electron emitting payload operating under the experimental conditions for the proposed initial PRECEDE launch. The results of Baum et al. (1975) indicate that following accelerator pulse initiation the vehicle charges to a large positive value, undergoes a series of damped charge oscillations to account for electron momentum and then decays to a small (less than 30 volts) positive steady-state potential. The transient vehicle charging theory indicates the vehicle attains a steady-state value in times comparable to the collision time of secondary electrons, on the order of 10 to 50 microseconds.

The vehicle skin potential during the PRECEDE experiment was monitored using an onboard retarding potential analyser (RPA). The return current to the RPA as a function of retarding voltage is compared to predicted secondary electron spectra to obtain an effective vehicle skin potential. The frequency response of the instrument was not sufficient to measure the large potential oscillations predicted theoretically and the RPA results are limited to a determination of the steady-state vehicle potential.

The RPA was located on the side of the PRECEDE vehicle as shown in Fig. 5. The electrons collected by the RPA, located at 90° with respect to the electron beam accelerator, was influenced by vehicle alignment with respect to the geomagnetic field, the location of the ionized cloud, and the vehicle skin potential. Since the secondary electron production was mainly in front of the vehicle, as shown in Fig. 5, only electrons scattered at certain angles entered the RPA. The trajectories of these electrons were governed by their geomagnetic confinement, as well as secondary collisions. The total return current to the RPA was approximately the fraction of RPA area to the total vehicle skin area. The dimensions of the electron accelerator payload and vehicle are shown in Fig. 5. The effective collecting area of the payload presented to the returning electrons varied with vehicle orientation and electron energy.

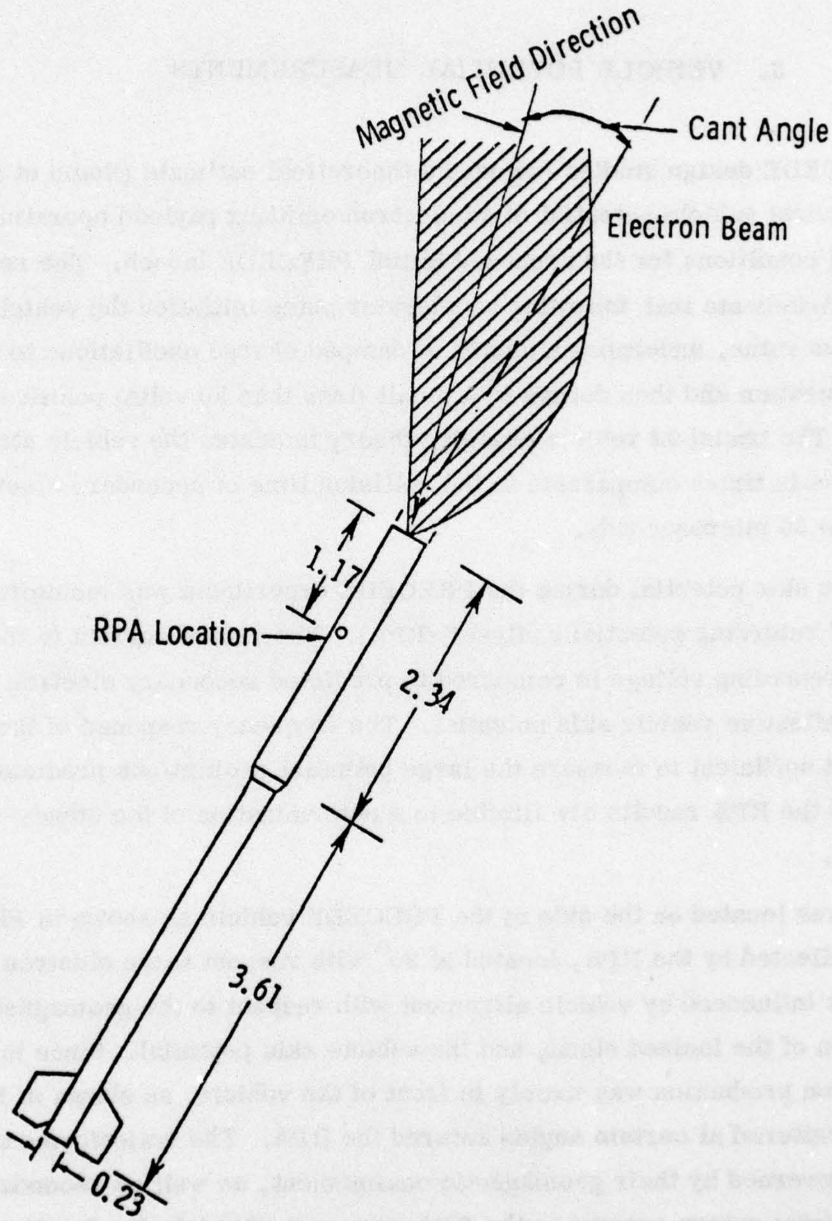


Figure 5. Location of the Retarding Potential Analyzer on the PRECEDE Vehicle. The Dimensions Are Given in Meters.

A typical RPA data frame is shown in Fig. 6. The retarding voltage was stepped through a sequency of 14, 0, -17, -33, 0, -120, and -550 volts in two second intervals equivalent to the electron beam pulse period. A retarding potential of -1960 volts was also used, but failed to operate reliably. The nominal 16 second RPA data frame represents an altitude increment of approximately 10 km at 100 km and 7 km at 110 km in the PRECEDE trajectory.

A 5 volt accelerator grid was placed in front of the retarding grid to ensure collection of electrons in the vicinity of the RPA. The entrance aperture of the RPA was 3.5 cm^2 and the instrument design allowed acceptance of electrons as much as 80 degrees from normal.

Figure 6 indicates the RPA dynamic range extended to currents as low as 10^{-10} amps. This collection current infers ambient electron densities as low as $10^2 cm^{-3}$ were measurable. However, RPA currents were not detectable when the electron accelerator was turned off during the PRECEDE experiment, even when a positive 14 volts was placed on the retarding grid. It is speculated the inability to measure ambient atmospheric electron densities is due to the vehicle orientation with respect to the geomagnetic field and the possibility of a slight negative charge on the vehicle skin, built-up after the electron accelerator was turned off.

The RPA current is the integral of all electrons having energy greater than the retarding potential. Thus, accounting for the 5 volt accelerating potential, a -17 volt retarding potential would be a sum of all electrons having energy of greater than 12 volts, etc. In the absence of a negative vehicle skin potential, the retarding voltages of +14 and 0 volts should show the same return current. This was indeed borne out by the RPA data. Similarly, if the vehicle potential was above 28 volts, the RPA current at -33 volts retarding potential would be equal to the 0 volt RPA electron current. This condition was not met even at apogee, indicating that the vehicle skin potential at no time exceeded 28 volts steady-state.

A spin modulation was presented on most of the RPA data and was most prominant at large retarding potentials. The current modulation was caused by the asymmetrical area of the RPA projected across the geomagnetic field and the electron excited atmosphere as the vehicle spun. The RPA was also shielded by the vehicle

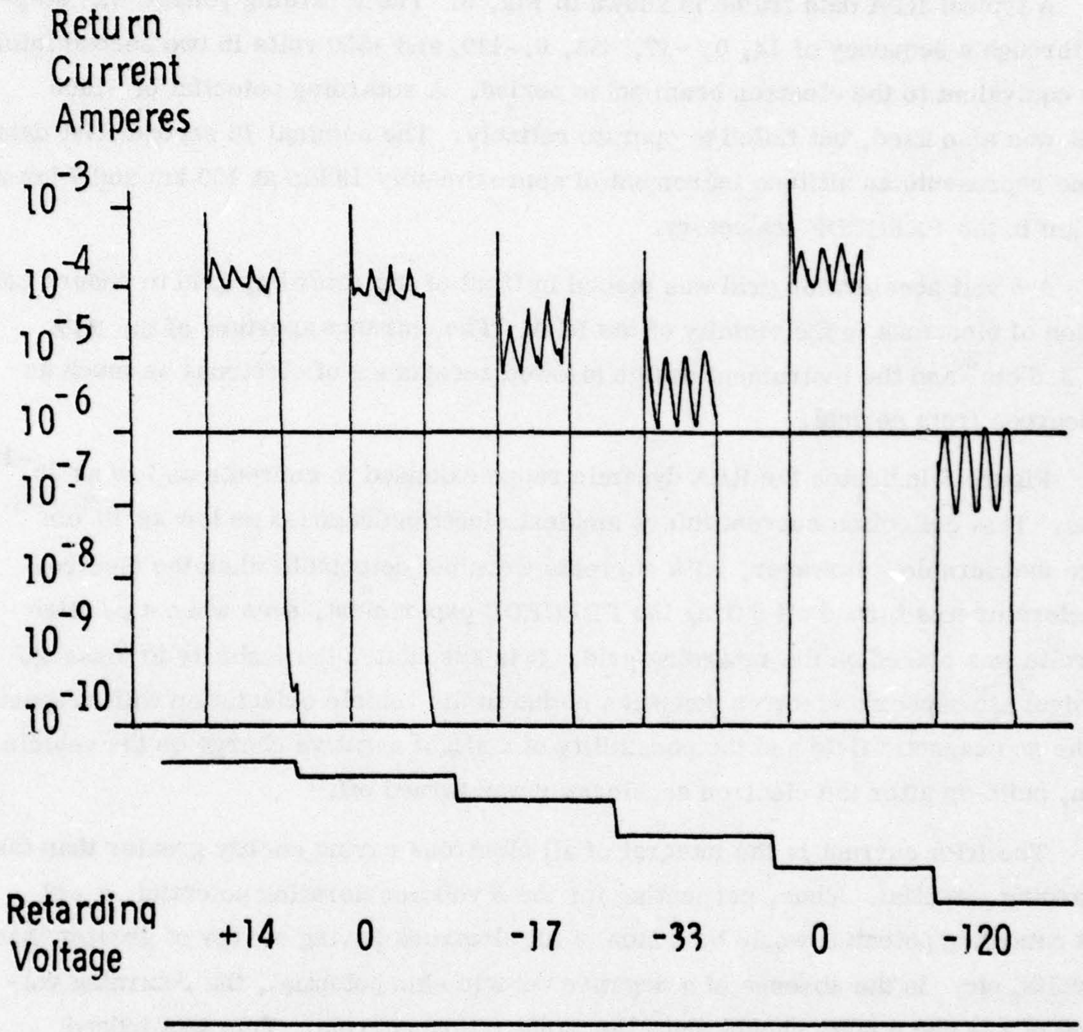


Figure 6. Return Current Collected by the Retarding Potential Analyzer at Various Retarding Voltages in the 112 to 116 km Altitude Range During Payload Ascent. Each Retarding Potential Was Applied for Two Seconds Equivalent to the Period of the Pulsed Accelerator Which Was Square Wave Modulated at 0.5 Hz.

from the highly excited atmosphere during one half of its spin, limiting collection electrons to a small angular distribution of scattered secondary electrons.

In order to obtain a vehicle skin potential from the RPA returns, a simplified model of the electron energy spectra was used. Here it was assumed that once the secondary electrons were formed, they traveled in a gyrating path around the geomagnetic field until they entered the RPA. The geometric orientation of the RPA was, thus, convoluted with the angular dependence of the secondary electron production spectra and the orientation of the electron beam. From this convolution the electron flux was derived for several vehicle orientations as a function of electron energy. The electron flux was then integrated as a function of effective retarding potential on the RPA for a primary electron of a given initial trajectory. Finally, a Monte Carlo technique was used to account for 30° divergence angle in the electron beam emanating from the accelerator and the probability of secondary electron production of a given energy and scattering angle. A mean size of one thermal electron Larmor radius was used as a sample grid size in the calculation. The energy distribution of the electrons collected by the RPA was determined by the angular orientation of the vehicle axis with the geomagnetic field and the orientation of the sensor with respect to the roll axis. Both the total integrated secondary electron current and the relative energy dependence of the electron current changed with orientation of the roll axis. In the absence of a simple roll dependence for the electron flux incident on the RPA, a maximum return current was assumed at all retarding potentials presumably equivalent to the peak values of the spin modulated currents of Fig. 6. Based on the laboratory measurements of Opal et al., (1971), the integrated cross-section for the production of secondary electrons by a 3 kV primary is shown in Fig. 7. The cross-section was in turn combined with the geometric factors to determine the electron flux at the RPA for various retarding voltages.

The integrated production cross-section of Fig. 7 was convoluted with the RPA returns from the PRECEDE experiment (see Fig. 6) and with altitude to produce an estimated vehicle skin potential. The effects of change in altitude and change in pitch angle of the vehicle with respect to the geomagnetic field, between retarding potential measurements, were considered in the calculation of the vehicle skin potential. The

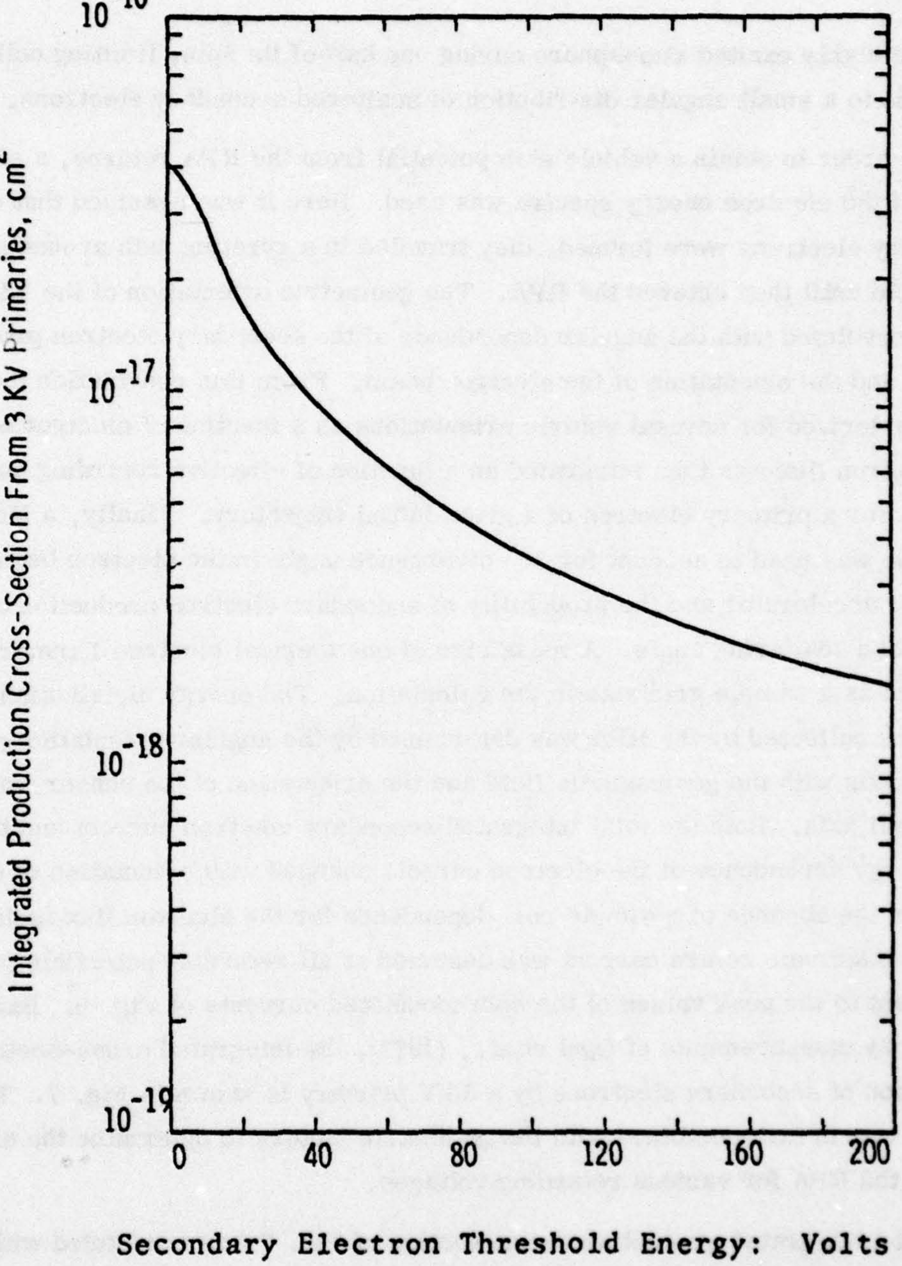


Figure 7. Integral Cross Sections for the Production By 2.5 kV Primary Electrons of Secondary Electrons With Energy Greater Than the Threshold Indicated.

resulting vehicle potential as a function of altitude is known in Fig. 8. The horizontal error bars represent the altitude extent over which a particular set of RPA readings were taken. The vertical error bars are due to the variations in current introduced by the spin modulation of the RPA. The maximum skin potential during the experiment was approximately 27 volts at apogee. Slightly larger vehicle potentials were observed on the descent trajectory compared to the equivalent upleg altitude. This asymmetry is presumably due to the greater payload velocity across of the geomagnetic field during descent which causes shorter electron beam dose times for each given volume element. The result of which would be smaller electron densities and thus a slightly larger vehicle potential.

A theoretical steady-state vehicle potential may be estimated by using Langmuir probe theory together with steady-state electron concentrations associated with the electron beam ionized cloud. In the steady-state case, it is assumed a vehicle to plasma potential is established to provide an electron return current to the payload equivalent to the accelerator current. The return current to the vehicle skin, which must balance the outgoing current is given by:

$$I_r = I = n_e u_e e A_v \quad , \tag{1}$$

where n_e is the number density of electrons near the vehicle, u_e is the drift velocity toward the vehicle, e the electron charge, and A_v is the area of the vehicle skin. At the altitudes of interest, the electron mean free path varies from several centimeters to several meters, much larger than the Debye length.

If the secondary electrons in the vicinity of the vehicle are not greatly depleted, their number density can be approximated by the steady-state concentration,

$$n_e(0) \simeq \left[P(0)/\alpha(0)\right]^{1/2} \quad , \tag{2}$$

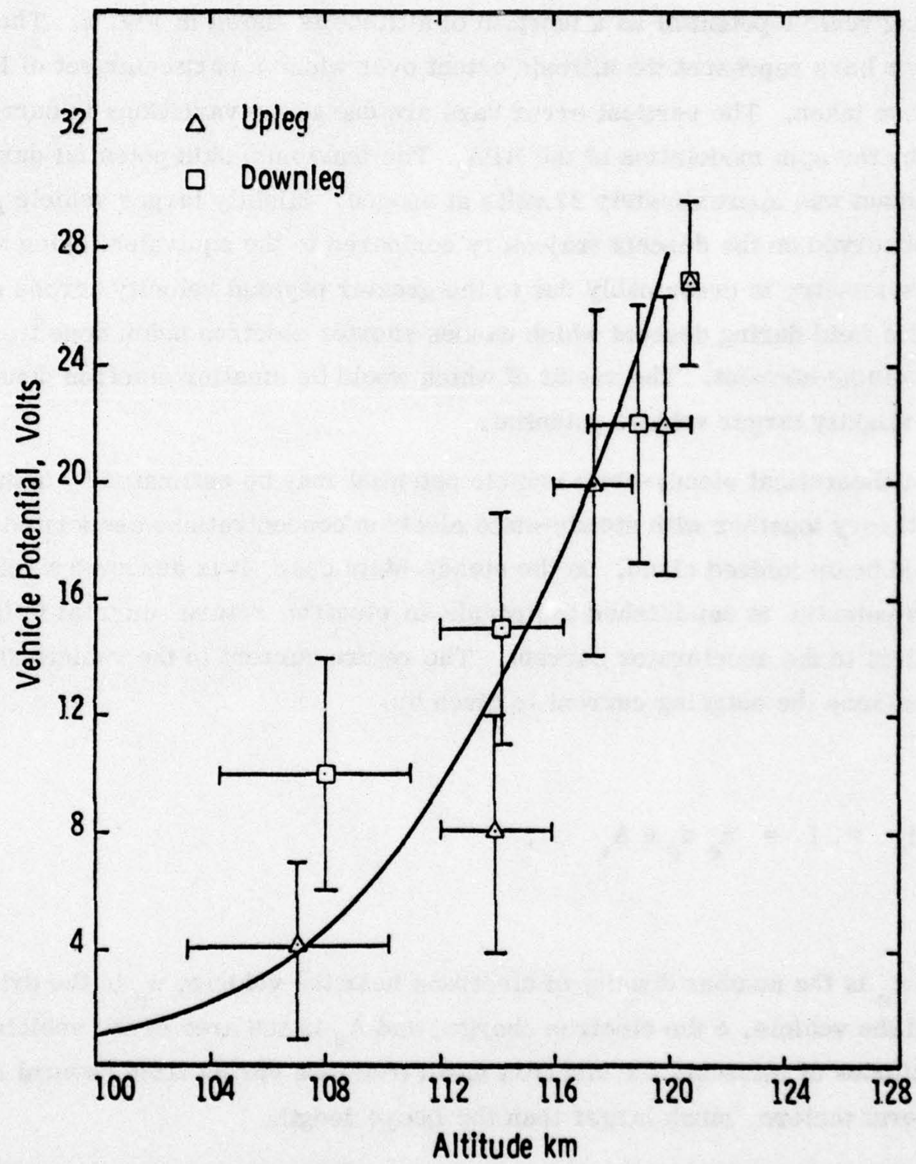


Figure 8. The Vehicle Potential Inferred From the RPA Measurements and the Potential Estimated Assuming Steady-State Langmuir Probe Theory.

where P(0) is the ionization rate near the skin of the vehicle, and $\alpha(0)$ is the electron recombination rate in the same region. The production rate P(0) can be approximated by the emperical relationship,

$$P(0) \simeq 1.86 \times 10^{-3} \, nIV^{-5/2} \, cm^{-3} sec^{-1} \quad , \tag{3}$$

by fitting to laboratory data by Grün (1957) with magnetic field confinement described by Berger et al., (1970, 1974). Here, V is the electron beam voltage in kV and I its current in amperes. The atmospheric density, n, in cm^{-3}, is taken to be mainly N_2. Clearly, corrections for ionization cross-section for O and O_2 should be made if an accurate number is to be obtained. However, these corrections are not considered significant compared to errors introduced in the effects of orientation and the assumptions of homogeneity of the electron beam source.

The recombination rate near the vehicle, $\alpha(0)$, is assumed to be $1 \times 10^{-7} cm^3/sec$, comparable to the NO^+ recombination rate at $T_e \simeq 0.5$ eV (Huang et al., 1975) and typical of ion recombination rates observed in the upper atmosphere. Thus, the electron density in the vicinity of the vehicle is

$$n_e(0) \cong 136 \, V^{-5/4} \, I^{1/2} \, n^{1/2} \, cm^{-3} \quad . \tag{4}$$

In the 100 to 120 km altitude range, atmospheric number density varies between 10^{13} and $5 \times 10^{11} cm^{-3}$. Thus, the electron mean free path is at all times much greater than the Debye sheath at steady-state. The vehicle skin, if perfectly conducting, would behave much like a Langmuir probe (Langmuir and Compton, 1931). The return current, using Langmuir's solution for the case when the probe potential is larger than a few tenths of a volt, is

$$I_r = \left(\frac{n_e \langle c_e \rangle}{4}\right) \left(1 + \frac{2e\phi_v}{kT_e}\right)^{1/2} eA_v \quad , \tag{5}$$

where $\langle c_e \rangle$ is the mean thermal speed of the electrons, ϕ_v is the vehicle potential, k Boltzmann's constant, and T_e is the plasma temperature.

Solving for the vehicle potential at steady-state by combining Eqs. (4) and (5) yields

$$\phi_v = \frac{kT_e}{2e} \left(\frac{1.4 \times 10^{-7}\ m_e\ I\ V^{5/2}}{e^2\ A_v^2\ n\ kT_e} - 1\right) \tag{6}$$

where m_e is the electron mass, I the current in amperes, V the beam voltage in kV, e the electronic charge and A_v the vehicle area in cm^2. Substituting representative values into Eq. (6), a theoretical vehicle potential, which is a function of vehicle orientation was obtained.

The vehicle skin potential is a function of the total area of the vehicle as well as the orientation of the vehicle with respect to the geomagnetic field. Because the electrons are essentially restricted from moving across geomagnetic field lines, an effective area was used in the calculation of vehicle skin potential. This area has been taken to be the vehicle cross-sectional area normal to the geomagnetic field, plus the added cross-section provided by the Larmor radius of a mean secondary electron. At high vehicle potentials, some distortion of the field lines may result, giving a larger effective vehicle skin area (Linson, 1969). The return current to the RPA is also affected by its orientation with respect to the geomagnetic field, and it would see a maximum electron flux if the aperture of the RPA was field aligned. The predicted vehicle skin potential was, thus, tailored to the specific geometry associated with the vehicle orientation.

The vehicle was canted with respect to the geomagnetic field during the entire period of electron beam operation, processing between 9 and 33^{o}. The effective area presented to the backscattered electrons varied from 3.5×10^{3} cm^{2} to 1.0×10^{4} cm^{2}, normal to the geomagnetic field, compared to a total vehicle skin area of approximately 5.4×10^{4} cm^{2}. The theoretical estimate of vehicle skin potential was obtained by combining the altitude dependence of the vehicle cant angle, atmosphere number density, and velocity across the geomagnetic field lines. The number density of electrons in the vicinity of the vehicle is a function of all three parameters. However, calculations become somewhat simplified when the vehicle is moving along the geomagnetic field, and a steady-state electron concentration could be established. The vehicle potential determined theoretically by the steady-state model is shown in Fig. 8 along with the experimentally determined values. The theoretical curve was produced from Eq. (6) using the PRECEDE nominal accelerator operating parameters, 2.5 kV and 0.8 amperes, and a representative Jacchia (1971) model atmosphere. The theoretical approximation indicates the vehicle potential is inversely proportional to atmospheric number density and provides an estimated vehicle potential of 2.8 volts at 104 km and 28 volts at 120 km in good agreement with the experimental results.

4. REFERENCES

Baum, H. R., F. Bien, and K. Tait, "An Analysis of Transient Vehicle Charging in the EXCEDE Experiment, Aerodyne Research, Inc.", Report RR-65, 1975.

Berger, M. J., S. M. Seltzer and K. Maeda, "Energy Deposition by Auroral Electrons in the Atmosphere", J. Atmos. and Terr. Phys., 32, 1015, 1970.

Berger, M. J., S.M. Seltzer, and K. Maeda, "Some New Results on Electron Transport in the Atmosphere", J. Atmos. and Terr. Phys., 36, 591, 1974.

Cambou, F., V. S. Dokoukime, V. N. Ivchenko, G. G. Managadze, V. V. Migulin, O.K. Nazarenko, A.T. Nesmyanovich, A.Kh. Pyatsi, R.Z. Sagdeev and I.A. Zhulin, "The Zarnitza Rocket Experiment on Electron Injection", Space Research XV, Akadamie-Verlag, Berline, 1975.

Davis, T.N., T.J. Hallinan, G.D. Mead, J.M. Mead, N.C. Trichel, and W.N. Hess, "Artificial Auroral Experiment: Ground Based Measurements of Auroral Rays", J. Geophys. Res., 76, 6082, 1971.

Grun, A.E., "Lumneszenz Photometrische Messungen Des Energie Absorption Un Strahlungsfeld Von Electronenguellen Eindemensionaler Fall in Ruft", Z. Naturforsh , A, 12, 89, 1959.

Hess, W. N., M.C. Trichel, T. N. Davis, W.C. Beggs, G.E. Kraft, E.G. Strassinopoulos, and E.J.R. Maier, "Artificial Aurora Equipment: The Equipment and Principal Results", J. Geophys. Res., 76, 6067, 1971.

Huang, C.M., Biondi, M.A., and R. Johnsen, "Variation of Electron NO^+ Ion Recombination Coefficient with Electron Temperature", Phys. Rev. A., 11, 901, 1975.

Jacchia, L.G., "Revised Static Models of the Thermosphere and Exosphere with Emperical Temperature Profiles", Spec. Rep., 332, Smithson. Astrophys. Observ., Cambridge, Mass., 1971.

Langmuir, I., and K. T. Compton, "Electrical Discharges in Gases, Part II Fundamental Phenomena in Electral Discharges", Rev. Mod. Phys. 3, 191, 1931.

Linson, L.M., "Current Voltage Characteristics of an Electron Emitting Satellite in the Ionosphere, "J. Geophys. Res., 74, 2368, 1969.

Miller, R.E., W.G. Fastie, and R.C. Isler, "Rocket Studies of Far-Ultraviolet Radiation in an Aurora", J. Geophys. Res., 73, 3353, 1968.

O'Neil, R.R., [illegible] P. Lee, E.R. Huppi and A.T. Stair, Jr., Project EXCEDE: SWIR Experiment, AFCRL-TR-73-0152, 1973.

Opal, C.B., W.K. Peterson, and E.C. Beaty, "Measurements of Secondary Electron Spectra Produced by Electron Impact Ionization of a Number of Simple Gases", *J. Chem. Phys.*, 55, 4100, 1971.

Rees, M.H. and D. Luckey, "Auroral Electron Energy Derived from Ratio of Spectroscopic Emissions 1. Model Computations", *J. Geophys. Res.*, 79,

Shepherd, G.G., "Gaseous Electronics in the Upper Atmosphere-Some Recent Observations of Atomic Oxygen 5577 and 5300A Emissions", 71, *Gaseous Electronics*, eds., J. Wm. McGowan and P.D. John, North-Holland Publishing Company-Amsterdam, 1974.

Slanger, T.G. and G. Black, "$O(^1S)$ Quenching Profile Between 75 and 115 km", *Planet. Space Sci.*, 21, 1757, 1973.

5. ACKNOWLEDGEMENTS

The author would like to than R. R. O'Neil and J. A. Sandock for providing the data on the PRECEDE RPA and help in analysing the data.

DISTRIBUTION LIST

DIRECTOR
DEFENSE ADVANCED RSCH PROJ AGENCY
ARCHITECT BUILDING
1400 WILSON BLVD.
ARLINGTON,VA 22209
ATTN LTC W A WHITAKER

DIRECTOR
DEFENSE ADVANCED RSCH PROJ AGENCY
ARCHITECT BUILDING
1400 WILSON BLVD.
ARLINGTON,VA 22209
ATTN MAJOR GREGORY CANAVAN

DEFENSE DOCUMENTATION CENTER
CAMERON STATION
ALEXANDRIA,VA 22314
ATTN TC

DEFENSE DOCUMENTATION CENTER
CAMERON STATION
ALEXANDRIA,VA 22314
ATTN TC

DEFENSE NUCLEAR AGENCY
WASHINGTON,DC 20305
ATTN RAAE CHARLES A BLANK

DIRECTOR
DEFENSE NUCLEAR AGENCY
WASHINGTON,DC 20305
ATTN TITL TECH LIBRARY

DIRECTOR
DEFENSE NUCLEAR AGENCY
WASHINGTON,DC 20305
ATTN TITL TECH LIBRARY

DIRECTOR
DEFENSE NUCLEAR AGENCY
WASHINGTON,DC 20305
ATTN TISI ARCHIVES

DIRECTOR
DEFENSE NUCLEAR AGENCY
WASHINGTON,DC 20305
ATTN RAEV HAROLD C FITZ,JR

DIRECTOR
DEFENSE NUCLEAR AGENCY
WASHINGTON,DC 20305
ATTN RAAE MAJ. J. MAYO

DIRECTOR
DEFENSE NUCLEAR AGENCY
WASHINGTON,DC 20305
ATTN RAAE G. SOPER

DIRECTOR
DEFENSE NUCLEAR AGENCY
WASHINGTON,DC 20305
ATTN MAJOR R. BIGONI

DIR OF DEFENSE RSCH & ENGINEERING
DEPARTMENT OF DEFENSE
WASHINGTON DC 20301
ATTN DD/S&SS (OS) DANIEL BROCKWAY

DIR OF DEFENSE RSCH & ENGINEERING
DEPARTMENT OF DEFENSE
WASHINGTON,DC 20301
ATTN DD/S&SS DANIEL BROCKWAY

COMMANDER
FIELD COMMAND
DEFENSE NUCLEAR AGENCY
KIRTLAND AFB,NM 87115
ATTN FCPR

CHIEF LIVERMORE DIVISION
FLD COMMAND DNA
LAWRENCE LIVERMORE LABORATORY
P.O. BOX 808
LIVERMORE, CA 94550
ATTN FCPRL

COMMANDER/DIRECTOR
ATMOSPHERIC SCIENCES LABORATORY
U S ARMY ELECTRONICS COMMAND
WHITE SANDS MISSILE RANGE,NM 88002
ATTN DRSEL-BL-SY-A F. NILES 3 copies

COMMANDER/DIRECTOR
ATMOSPHERIC SCIENCES LABORATORY
U S ARMY ELECTRONICS COMMAND
WHITE SANDS MISSILE RANGE,NM 88002
ATT H. BALLARD 3 copies

COMMANDER
HARRY DIAMOND LABORATORIES
2800 POWDER MILL RD
ADELPHI MD 20783
ATTNDRXDO-NP, F.H. WIMINETZ

COMMANDER
U S ARMY NUCLEAR AGENCY
FORT BLISS,TX 79916
ATTN MONA-WE

DIRECTOR
BMD ADVANCED TECH CTR
HUNTSVILLE,AL 35807
ATTN ATC-T, M CAPPS

DIRECTOR
BMD ADVANCED TECH CTR
HUNTSVILLE,AL 35807
ATTN ATC-O,W.DAVIES

DEP.CHIEF OF STAFF FOR RSCH, DEV&ACQ
DEPARTMENT OF THE ARMY
WASHINGTON DC 20310
ATTN MCB DIVISION

DEP.CHIEF OF STAFF FOR RSCH,DEV&ACQ
DEPARTMENT OF THE ARMY
WASHINGTON,DC 20310
ATTN DAMA-CSZ-C

DEP.CHIEF OF STAFF FOR RSCH, DEV&ACQ
DEPARTMENT OF THE ARMY
WASHINGTON DC 20310
ATTN DAMA-WSZC

COMMANDER
US ARMY ELECTRONICS COMMAND
FORT MONMOUTH,N.J. 37703
ATT DRSEL 5 copies

DIRECTOR
US ARMY BALLISTIC RESEARCH LABS
ABERDEEN PROVING GROUNDS,MD 21005
ATTN DRXBR-AM,G. KELLER

COMMANDER
US ARMY ELECTRONICS COMMAND
FORT MONMOUTH,N.J. 37703
ATN STANLEY KRONENBERGER

DIRECTOR
US ARMY BALLISTIC RESEARCH LABS
ABERDEEN PROVING GROUNDS,MD 21005
ATTN DRXRD-BSP,J.HEIMERL

COMMANDER
US ARMY ELECTRONICS COMMAND
FORT MONMOUTH,N.J. 37703
ATN WEAPONS EFFECTS SECTION

DIRECTOR
US ARMY BALLISTIC RESEARCH LABS
ABERDEEN PROVING GROUNDS,MD 21005
ATTN JOHN MESTER

COMMANDER
US ARMY FOREIGN SCIENCE & TECH CTR
220 7TH STREET,NE
CHARLOTTESVILLEVA 22901
ATTN ROBERT JONES

DIRECTOR
US ARMY BALLISTIC RESEARCH LABS
ABERDEEN PROVING GROUNDS,MD 21005
ATTN TECH LIBRARY

CHIEF
US ARMY RESEARCH OFFICE
P.O. BOX 12211
TRIANGLE PARK,N.C. 27709
ATT ROBERT MACE

COMMANDER
US ARMY ELECTRONICS COMMAND
FORT MONMOUTH,N.J. 37703
ATTN INST FOR EXPL RESEARCH

COMMANDER
NAVAL OCEANS SYSTEMS CENTER
SAN DIEGO,CA 92152
ATTN CODE 2200 ILAN ROTHMULLER

COMMANDER
NAVAL OCEANS SYSTEMS CENTER
SAN DIEGO,CA 92152
ATTN CODE 2200 WILLIAM MOLER

COMMANDER
NAVAL OCEANS SYSTEMS CENTER
SAN DIEGO,CA 92152
ATTN CODE 2200 HERBERT HUGHES

COMMANDER
NAVAL OCEANS SYSTEMS CENTER
SAN DIEGO,CA 92152
ATTN CODE 2200 RICHARD PAPPERT

COMMANDER
NAVAL OCEANS SYSTEMS CENTER
SAN DIEGO,CA 92152
ATTN CODE 2200JURGEN R RICHTER

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 7712 DOUGLAS P MCNUTT

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 7701 JACK D BROWN

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 2600 TECH LIB

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 7127 CHARLES Y JOHNSON

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 7700 TIMOTHY P COFFEY

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 7709 WAHAB ALI

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 7750 DARRELL F STROBEL

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 7750 PAUL JULUENNE

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 7750 J. FEDDER

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 7750 S. OSSAKOW

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON,DC 20375
ATTN CODE 7750 J. DAVIS

COMMANDER
NAVAL SURFACE WEAPONS CENTER
WHITE OAK,SILVER SPRING,MD 20910
ATTN CODE WA501 NAVY NUC PRGMS OFF

COMMANDER
NAVAL SURFACE WEAPONS CENTER
WHITE OAKS,SILVER SPRING,MD 20910
ATTN TECHNICAL LIBRARY

SUPER INTENDENT
NAVAL POST GRADUATE SCHOOL
MONTEREY,CA 93940
ATTN TECH REPORTS LIBRARIAN

COMMANDER
NAVAL ELECTRONICS SYSTEMS COMMAND
NAVAL ELECTRONICS SYSTEMS COMMAND HQ!
ATTN PME 117

COMMANDER
NAVAL INTELLIGENCE SUPPORT CTR
4301 SUITLAND RD. BLDG 5
WASHINGTON,DC20390
ATTN DOCUMENT CONTROL

AF GEOPHYSICS LABORATORY,AFSC
HANSCOM AFB, MA 01731
ATTN LKB KENNETH S W CHAMPION

AF GEOPHYSICS LABORATORY,AFSC
HANSCOM AFB, MA 01731
ATTN OPR ALVA T STAIR

AF GEOPHYSICS LABORATORY,AFSC
HANSCOM AFB, MA 01731
ATTN OPR-1 J. ULWICK

AF GEOPHYSICS LABORATORY,AFSC
HANSCOM AFB, MA 01731
ATTN OPR-1 R. MURPHY

AF GEOPHYSICS LABORATORY,AFSC
HANSCOM AFB, MA 01731
ATTN OPR-1J. KENNEALY

AF GEOPHYSICS LABORATORY,AFSC
HANSCOM AFB, MA 01731
ATTN PHG JC MCCLAY

AF GEOPHYSICS LABORATORY,AFSC
HANSCOM AFB, MA 01731
ATTN LKD ROCCO NARCIS

AF GEOPHYSICS LABORATORY,AFSC
HANSCOM AFB, MA 01731
ATTN LKO,R. HUFFMAN

AF WEAPONS LABORATORY,AFSC
KIRTLAND,AFB,NM 87117
ATTN MAJ.GARY GANONG,DYM

COMMANDER
ASD
WPAFB,OH 45433
ATTN ASD-YH-EX LTC ROBERT LEVERETTE

SAMSO/AW
POST OFFICF BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES,CA 90009
ATTNSZJ MAJOR LAWRENCE DOAN

SAMSO/SW
P.O. BOX 92960
WORLDWAY POSTAL CENTER
LOS, ANGELES,CA 90009
ATTN AW

AFTAC
PATRICK AFB,FL 32925
ATTN TECH LIBRARY

AFTAC
PATRICK AFB,FL 32925
ATTN TD

HQ
AIR FORCE SYSTEMS COMMAND
ANDREWS AFB
WASHINGTON,DC 20331
ATTN DLS

HQ
AIR FORCE SYSTEMS COMMAND
ANDREWS AFB
WASHINGTON,DC 20331
ATTN TECH LIBRARY

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

HQ
AIR FORCE SYSTEMS COMMAND
ANDREWS AFB
WASHINGTON,DC 20331
ATTN DLCAE

HQ
AIR FORCE SYSTEMS COMMAND
ANDREWS AFB
WASHINGTON,DC 20331
ATTN DLTW

HQ
AIR FORCE SYSTEMS COMMAND
ANDREWS AFB
WASHINGTON,DC 20331
ATTN DLXP

HQ
AIR FORCE SYSTEMS COMMAND
ANDREWS AFB
WASHINGTON,DC 20331
ATTNSDR

HQ USAF/RD
WASHINGTON,DC 20330
ATTN PDQ

COMMANDER
ROME AIR DEVELOPMENT CTR
GRIFFISS AFB,NY 13440
ATTN JJ. SIMONS OCSC

DIVISION OF MILITARY APPLICATION
U S ENERGY RSCH & DEV ADMIN
WASHINGTON,DC 20545
ATTN DOC CON

LOS ALAMOS SCIENTIFIC LABORATORY
P.O. BOX 1663
LOS,ALAMOS, NM 87545
ATTN DOC CON FOR R A JEFFRIES

LOS ALAMOS SCIENTIFIC LABORATORY
P.O. BOX 1663
LOS,ALAMOS, NM 87545
ATTN DOC CON FOR CR MEHL ORG 5230

LOS ALAMOS SCIENTIFIC LABORATORY
P.O. BOX 1663
LOS,ALAMOS, NM 87545
ATTN DOC CON FOR H V ARGO

LOS ALAMOS SCIENTIFIC LABORATORY
P.O. BOX 1663
LOS,ALAMOS, NM 87545
ATTN DOC CON FOR M. TIERNEY J-10

LOS ALAMOS SCIENTIFIC LABORATORY
P.O. BOX 1663
LOS,ALAMOS, NM 87545
ATTN DOC CON FOR ROBERT BROWNLEE

LOS ALAMOS SCIENTIFIC LABORATORY
P.O. BOX 1663
LOS,ALAMOS, NM 87545
ATTN DOC CON FOR WILLIAM MAIER

SANDIA LABORATORIES
P.O. BOX 5800
ALBUQUERQUE,NM 87115
ATT DOC CONT.
FOR MORGAN KRAMMA ORG 5720

LOS ALAMOS SCIENTIFIC LABORATORY
P.O. BOX 1663
LOS,ALAMOS, NM 87545
ATTN DOC CON FOR JOHN ZINN

SANDIA LABORATORIES
P.O. BOX 5800
ALBUQUERQUE,NM 87115
ATT DOC CONT.
FOR FRANK HUDSON ORG 1722

LOS ALAMOS SCIENTIFIC LABORATORY
P.O. BOX 1663
LOS,ALAMOS, NM 87545
ATTN DOC CON FOR REFERENCE LIBRARY
ANN BEYER

SANDIA LABORATORIES
P.O. BOX 5800
ALBUQUERQUE,NM 87115
ATT DOC CONT.
FOR ORG 3422-1 SANDIA REPTS COLL.

SANDIA LABORATORIES
LIVERMORE LABORATORY
P.O. BOX 965
LIVERMORE,CA 94556
ATTN DOC CONTROL FOR
THOMAS COOK ORG 8000

ARGONNE NATIONAL LABORATORY
RECORDS CONTROL
9700 SOUTH CASS AVENUE
ARGONNE, IL 60439
ATTN DOC CON FOR A C WAHL

SANDIA LABORATORIES
P.O. BOX 5800
ALBUQUERQUE,NM 87115
ATT DOC CONT. FOR
W.D. BROWN ORG 1353

ARGONNE NATIONAL LABORATORY
RECORDS CONTROL
9700 SOUTH CASS AVENUE
ARGONNE, IL 60439
ATTN DOC CON FOR DAVID W GREEN

SANDIA LABORATORIES
P.O. BOX 5800
ALBUQUERQUE,NM 87115
ATT DOC CONT. FOR
L. ANDERSON ORG 1247

ARGONNE NATIONAL LABORATORY
RECORDS CONTROL
9700 SOUTH CASS AVENUE
ARGONNE, IL 60439
ATTN DOC CON FOR LIR SVCS RPTS SEC

ARGONNE NATIONAL LABORATORY
RECORDS CONTROL
9700 SOUTH CASS AVENUE
ARGONNE, IL 60439
ATTN DOC CON FOR S GARELNICK

ARGONNE NATIONAL LABORATORY
RECORDS CONTROL
9700 SOUTH CASS AVENUE
ARGONNE, IL 60439
ATTN DOC CON FOR GERALD T REEDY

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
P.O. BOX 808
LIVERMORE CA 94550
ATTN W.H. DUEWER GEN L-404

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
P.O. BOX 808
LIVERMORE CA 94550
ATTN JULIUS CHANG L-71

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
P.O. BOX 808
LIVERMORE CA 94500
G.R. HAUGEN L-404

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
P.O. BOX 808
LIVERMORE CA 94550
ATTN D.J. WUERBLES L-142

CALIFORNIA, STATE OF
AIR RESOURCE BOARD
9528 TELSTA AVE
AL MONTE, CA 91731
ATTNLEO ZAFONTE

CALIFORNIA INSTITUTE OF TECHNOLOGY
JET PROPULSION LABORATORY
4800 OAK GROVE DRIVE
PASADENA,CA 91103
ATTN JOSEPH A JELLO

U S ENERGY RSCH & DEV ADMIN
DIVISION OF HEADQUARTERS SERVICES
LIBRARY BRANCH G-043
WASHINGTON,DC 20545
ATTN DOC CON FOR CLASS TECH LIB

DEPARTMENT OF TRANSPORTATION
OFFICE OF THE SECRETARY
TAD-44,1,ROOM 10402-R
400 7TH STREET S.W.
WASHINGTON,DC 20590
ATTN SAMJEL C CORONITI

NASA
GODDARD SPACE FLIGHT CENTER
GREENBELT,MD 20771
ATTN A C AIKEN

NASA
GODDARD SPACE FLIGHT CENTER
GREENBELT,MD 20771
ATTN A TEMPKIN

NASA
GODDARD SPACE FLIGHT CENTER
GREENBELT,MD 20771
ATTN A J BAUER

NASA
600 INDEPENDENCE AVENUE S W
WASHINGTON,DC 20546
ATTN R FELLOWS

NASA
GODDARD SPACE FLIGHT CENTER
GREENBELT,MD 20771
ATTN TECHNICAL LIBRARY

NASA
600 INDEPENDENCE AVENUE S W
WASHINGTON,DC 20546
ATTN A SCHARDT

NASA
GODDARD SPACE FLIGHT CENTER
GREENBELT,MD 20771
ATTN J. SIRY

NASA
600 INDEPENDENCE AVENUE S W
WASHINGTON,DC 20546
ATTN M TEPPER

NASA
600 INDEPENDENCE AVENUE S W
WASHINGTON,DC 20546
ATTN A GESSOW

NASA
LANGLEY RESEARCH CENTER
LANGLEY STATION
HAMPTON,VA 23365
ATTN CHARLES SCHEXNAYDER MS-168

NASA
600 INDEPENDENCE AVENUE S W
WASHINGTON,DC 20546
ATTN D P CAUFFMAN

NASA
AMES RESCH CENTER
MOFFETT FIELD,CA 90435
ATTN N-254-4 WALTER L. STARR

NASA
600 INDEPENDENCE AVENUE S W
WASHINGTON,DC 20546
ATTN LTC D R HALLENBECK CODE SG

NASA
AMES RESEARCH CENTER
MOFFETT FIELD,CA 94035
ATTN N-254-4 R WHITTEN

NASA
AMES RESEARCH CENTER
MOFFETT FIELD,CA 94035
ATTN N-254-4 ILIA G POPPOFF

NASA
GEORGE C MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE,AL 35812
ATTN W T ROBERTS

NASA
AMES RESEARCH CENTER
MOFFETT FIELD,CA 94036
ATTN N-254-3 NEIL H FARLOW

NASA
GEORGE C MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE,AL 35812
ATTN R D HUDSON

NASA
GEORGE C MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, AL 35812
ATTN C R BALCHER

NASA
GEORGE C MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE,AL 35812
ATTN R CHAPPELL

NASA
GEORGE C MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, AL 35812
ATT N H STONE

ALBANY METALLURGY RESEARCH CENTER
U S BUREAU OF MINES
P.O. BOX 70
ALBANY,OR 97321
ATTN ELEANOR ARSHIRE

NASA
GEORGE C MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, AL 35812
ATT W A ORAN

CENTRAL INTELLIGENCE AGENCY
ATTN RD/SI RM 5G48 HQ BLDG
WASHINGTON DC 20505
ATTN NED/OSI-2G4R HQS

NASA
GEORGE C MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, AL 35812
ATT CODE ES22JOHN WATTS

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON,DC 20234
ATTN SEC OFFICER FOR ATTN JAMESS DEVOE

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON,DC 20234
ATTN SEC OFFICER
STANLEY ABRAMOWITZ

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON,DC 20234
ATTN SEC OFFICER FOR ATTN J COOPER

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON,DC 20234
ATTN SEC OFFICER FOR ATTN GEORGE A SINNATT

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON,DC 20234
ATTN SEC OFFICER FOR ATTN K KESSLER

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON,DC 20234
ATTN SEC OFFICER FOR ATTN M KRAUSS

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON,DC 20234
ATTN SEC OFFICER FOR
ATTN LEWIS H GEVANTMAN

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON,DC 20234
ATTN SEC OFFICER FOR ATTN JAMES DEVOE

NATIONAL OCEANIC & ATMOSPHERIC ADMIN
ENVIRONMENTAL RESEARCH LABORATORIES
DEPARTMENT OF COMMERCE
BOULDER,CO 80302
ATTN GEORGE C REID AERONOMY LAB

NATIONAL OCEANIC & ATMOSPHERIC ADMIN
ENVIRONMENTAL RESEARCH LABORATORIES
DEPARTMENT OF COMMERCE
BOULDER,CO 80302
ATTN ELDON FERGUSON

NATIONAL OCEANIC & ATMOSPHERIC ADMIN
ENVIRONMENTAL RESEARCH LABORATORIES
DEPARTMENT OF COMMERCE
BOULDER,CO 80302
ATTN FRED FEHSENFELD

AERO-CHEM RESEARCH LABORATORIES,INC
P.O. BOX 12
PRINCETON,NJ 08540
ATTN A FONTIJN

AERO-CHEM RESEARCH LABORATORIES,INC
P.O. BOX 12
PRINCETON,NJ 08540
ATTN H PERGAMENT

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

AERODYNE RESEARCH, INC.
BEDFORD RESEARCH PARK
CROSBY DRIVE
BEDFORD,MA 01731 ATTN F BIEN

AEROSPACE CORPORATION
P.O. BOX 92957
LOS ANGELES,CA 90009
ATTN T WIDHOPH

AERODYNE RESEARCH, INC.
BEDFORD RESEARCH PARK
CROSBY DRIVE
BEDFORD,MA 01731 ATTN M CAMAC

AEROSPACE CORPORATION
P.O. BOX 92957
LOS ANGELES,CA 90009
ATTN R J MCNEAL

AERONOMY CORPORATION
217 S NEIL STREET
CHAMPAIGN, IL 61820
ATTN A BOWHILL

AEROSPACE CORPORATION
P.O. BOX 92957
LOS ANGELES,CA 90009
ATTN R GROVE

AEROSPACE CORPORATION
P.O. BOX 92957
LOS ANGELES,CA 90009
ATTN N COHEN

AEROSPACE CORPORATION
P.O. BOX 92957
LOS ANGELES,CA 90009
ATTN IRVING M GARFUNKEL

AEROSPACE CORPORATION
P.O. BOX 92957
LOS ANGELES,CA 90009
ATTN HARRIS MAYER

AEROSPACE CORPORATION
P.O. BOX 92957
LOS, ANGELES, CA 90009
ATTN THOMAS D TAYLOR

AEROSPACE CORPORATION
P.O. BOX 92957
LOS ANGELES,CA 90009
ATTN SIDNEY W KASH

AEROSPACE CORPORATION
P.O. BOX 92957
LOS, ANGELES,CA 90009
ATTN V JOSEPHSON

AEROSPACE CORPORATION
P.O. BOX 92957
LOS,ANGELES,CA 90009
ATTN JULIAN REINHEIMER

AEROSPACE CORPORATION
P.O. BOX 92957
LOS, ANGELES,CA 90009
ATTN R D RAWCLIFFE

AVCO-EVERETT RESEARCH LABORATORY INC
2385 REVERE BEACH PARKWAY
EVERETT,MA 02149
ATTN TECHNICAL LIBRARY

AVCO-EVERETT RESEARCH LABORATORY INC
2385 REVERE BEACH PARKWAY
EVERETT,MA 02149
ATTN GEORGE SUTTON

AVCO-EVERETT RESEARCH LABORATORY INC
2385 REVERE BEACH PARKWAY
EVERETT,MA 02149
ATTN C W VON ROSENBERG JR

BATTELLE MEMORIAL INSTITUTE
505 KING AVENUE
COLUMBUS, OH 43201
ATTN DONALD J HAMMAN

BATTELLE MEMORIAL INSTITUTE
505 KING AVENUE
COLUMBUS, OH 43201
ATTN DONALD J HAM

BATTELLE MEMORIAL INSTITUTE
505 KING AVENUE
COLUMBUS,OH 43201
ATTN STOIAC

BATTELLE MEMORIAL INSTITUTE
505 KING AVENUE
COLUMBUS,OH 43201
ATTN RICHARD K THATCHER

BROWN ENGINEERING COMPANY,INC
CUMMINGS RESEARCH PARK
HUNTSVILLE,AL 35807
ATTN N PASSINO

THE TRUSTEES OF BOSTON COLLEGE
CHESTNUT HILL CAMPUS
CHESTNUT HILL, MA 02167
ATTN CHAIRMAN DEPT OF CHEM

BROWN ENGINEERING COMPANY,INC
CUMMINGS RESEARCH PARK
HUNTSVILLE,AL 35807
ATTN RONALD PATRICK

CALIFORNIA AT RIVERSIDE, UNIV OF
RIVERSIDE, CA 92502
ATTN ALAN C LLOYD

CALIFORNIA, STATE OF
AIR RESOURCES BOARD
9528 TELSTAR AVENUE
EL MONTE, CA 91731
ATTN LEO ZAFONTE

CALIFORNIA AT RIVERSIDE, UNIV OF
RIVERSIDE, CA 92502
ATTN JAMES N PITTS JR

CALSPAN CORPORATION
P.O. BOX 235
BUFFALO, NY 14224
ATTN C E TREANOR

CALIFORNIA AT SAN DIEGO, UNIV OF
3175 MIRAMAR ROAD
LA JOLLA, CA 92037
ATTN S C LIN

CALSPAN CORPORATION
P.O. BOX 235
BUFFALO,NY 14221
ATTN G C VALLEY

CALIFORNIA UNIVERSITY OF
BERKELEY CAMPUS ROOM 318
SPROUL HALL
BERKELEY,CA 94720
ATTN SEC OFFICER FOR HAROLD JOHNSTON

CALSPAN CORPORATION
P.O. BOX 235
BUFFALO,NY 14221
ATTN M G DUNN

CALIFORNIA UNIVERSITY OF
BERKELEY CAMPUS ROOM 318
SPROUL HALL
BERKELEY,CA 94720
ATTN SEC OFFICER FOR F MOZER

CALSPAN CORPORATION
P.O. BOX 235
BUFFALO,NY 14221
ATTN W WURSTER

CALIFORNIA UNIVERSITY OF
BERKELEY CAMPUS ROOM 318
SPROUL HALL
BERKELEY,CA 94720
ATTN SEC OFFICER FOR DEPT OF CHAM
W H MILLER

COLORADO,UNIVERSITY OF
OFFICE OF CONTRACTS AND GRANTS
380 ADMINISTRATIVE ANNEX BOULDER,CO 80302
ATTN A PHELPS JILA

OFFICE OF CONTRACTS AND GRANTS
380 ADMINISTRATIVE ANNEX
BOULDER, CO 80302
ATTN JEFFREY B PEARCE LASP

COLORADO,UNIVERSITY OF
OFFICE OF CONTRACTS AND GRANTS
380 ADMINISTRATIVE ANNEX
BOULDER,CO 80302
ATTN C BEATY JILA

COLORADO,UNIVERSITY OF
OFFICE OF CONTRACTS AND GRANTS
380 ADMINISTRATIVE ANNEX
BOULDER,CO 80302
ATTN C LINEBERGER JILA

COLORADO,UNIVERSITY OF
OFFICE OF CONTRACTS AND GRANTS
380 ADMINISTRATIVE ANNEX
BOULDER,CO 80302
ATTN CHARLES A BARTH LASP

COLUMBIA UNIVERSITY,THE TRUSTEES
IN THE CITY OF NEW YORK
LA MONT DOHERTY GEOLOGICAL
OBSERVATORY-TORREY CLIFF
PALISADES,NY 19064
ATTN B PHELAN

COLUMBIA UNIVERSITY,THE TRUSTEES OF
CITY OF NEW YORK
116TH STREET & BROADWAY
NEW YORK, NY 10027
ATTN RICHARD N ZARE

COLUMBIA UNIVERSITY, THE TRUSTEES OF
CITY OF NEW YORK
116TH & BROADWAY
NEW YORKNY 10027
ATTN SEC OFFICER H M FOLEY

CONCORD SCIENCES
P.O. BOX 119
CONCORD,MA 01742
ATTN EMMETT A SUTTON

DENVER,UNIVERSITY OF
COLORADO SEMINARY
DENVER RESEARCH INSTITUTE
P.O. BOX 10127DENVER, CO 80210
ATTN SEC OFFICER FOR MR VAN ZYL

DENVER,UNIVERSITY OF
COLORADO SEMINARY
DENVER RESEARCH INSTITUTE
P.O. BOX 10127DENVER,CO 80210
ATTN SEC OFFICER FOR DAVID MURCRAY

GENERAL ELECTRIC COMPANY
TEMPO-CENTER FOR ADVANCED STUDIES
816 STATE STREET (P.O DRAWER QQ)
SANTA BARBARA,CA 93102
ATTN DASAIC

GENERAL ELECTRIC COMPANY
TEMPO-CENTER FOR ADVANCED STUDIES
816 STATE STREET (P.O. DRAWER QQ)
SANTA BARBARA,CA 93102
ATTN WARREN S KNAPP

GENERAL ELECTRIC COMPANY
TEMPO-CENTER FOR ADVANCED STUDIES
816 STATE STREET (P.O DRAWEP)
SANTA BARBARA,CA 93102
ATTN TIM STEPHENS

GENERAL ELECTRIC COMPANY
TEMPO-CENTER FOR ADVANCED STUDIES
816 STATE STREET (P.O. DRAWFR QQ)
SANTA BARBARA,CA 93102
ATTN DON CHANDLER

GENERAL ELECTRIC COMPANY
TEMPO-CENTER FOR ADVANCED STUDIFS
816 STATE STREET (P.O. DRAWFR QQ)
SANTA BARBARA,CA 93102
ATTN B GAMBILL

GENERAL ELEC. CO.
SPACE DIVISION
VALLEY FORGE SPACE CTR
GODDARD BLVD
KING OF PRUSSIA
P.O. BOX 8555
PHILADELPHIA,PA 19101
ATTN M H BORTNER, SPACE SCIENCE LAB

GENERAL ELECTRIC COMPANY
SPACE DIVISION
VALLEY FORGE SPACE CENTER
GODDARD BLVD KING OF PRUSSIA
P.O. BOX 8555
PHILADELPHIA,PA 19101
ATTN J BURNS

GENERAL ELECTRIC COMPANY
SPACE DIVISION
VALLEY FORGE SPACE CENTER
GODDARD BLVD KING OF PRUSSIA
P.O. BOX 8555
PHILADELPHIA,PA 19101
ATTN F ALYEA

GENERAL ELECTRIC COMPANY
SPACE DIVISION
VALLEY FORGE SPACE CENTER
GODDARD BLVD KING OF PRUSSIA
P.O. BOX 8555
PHILADELPHIA,PA 19101
ATTN P ZAVITSANOS

GENERAL ELECTRIC COMPANY
SPACE DIVISION
VALLEY FORGE SPACE CENTER
GODDARD BLVD KING OF PRUSSIA
P.O. BOX 8555
PHILADELPHIA,PA 19101
ATTN R H EDSALL

GENERAL ELECTRIC COMPANY
SPACE DIVISION
VALLEY FORGE SPACE CENTER
GODDARD BLVD KING OF PRUSSIA
P.O. BOX 8555
PHILADELPHIA,PA 19101
ATTN T BAURER

GENERAL RESEARCH CORPORATION
P.O. BOX 3587
SANTA BARBARA,CA93105
ATTN JOHN ISE JR

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS,AK 99701
ATTN D HENDERSON

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS,AK 99701
ATTN J S WAGNER PHYSICS DEPT

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS,AK 99701
ATTN B J WATKINS

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS,AK 99701
ATTN T N DAVIS

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS,AK 99701
ATTN R PARTHASARATHY

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS,AK 99701
ATTN NEAL BROWN

LOWELL, UNIVERSITY OF
CENTER FOR ATMOSPHERIC RESEARCH
450 AIKEN STREET
LOWELL,MA 01854
ATTN G T BEST

LOCKHEED MISSILES AND SPACE COMPANY
3251 HANOVER STREET
PALO ALTO, CA 94394
ATTN JOHN KUMER DEPT 52-54

LOCKHEED MISSILES AND SPACE COMPANY
3251 HANOVER STREET
PALO,ALTO,CA 94304
ATTNJOHN KIMER DEPT 52-54

LOCKHEED MISSILES AND SPACE COMPANY
3251 HANOVER STREET
PALO,ALTO,CA 94304
ATTNJOHN B CLADIS DEPT 52-12

LOCKHEED MISSILES AND SPACE COMPANY
3251 HANOVER STREET
PALO,ALTO,CA 94304
ATTNBILLY M MCCORMAC DEPT 52-54

LOCKHEED MISSILES AND SPACE COMPANY
3251 HANOVER STREET
PALO,ALTO,CA 94304
ATTNTOM JAMES DEPT 52-54

LOCKHEED MISSILES AND SPACE COMPANY
3251 HANOVER STREET
PALO,ALTO,CA 94304
ATTNJ B REAGAN D/52-12

LOCKHEED MISSILES AND SPACE COMPANY
3251 HANOVER STREET
PALO,ALTO,CA 94304
ATTNMARTIN WALT DEPT 52-10

LOCKHEED MISSILES AND SPACE COMPANY
3251 HANOVER STREET
PALO,ALTO,CA 94304
ATTNRICHARD G JOHNSON DEPT 52-12

LOCKHEED MISSILES AND SPACE COMPANY
3251 HANOVER STREET
PALO,ALTO,CA 94304
ATTNROBERT D SEARS DEPT 52-14

LOCKHEED MISSILES AND SPACE COMPANY
3251 HANOVER STREET
PALO,ALTO,CA 94304
ATTNJ R WINKLER

INSTITUTE FOR DEFENSE ANALYSE
400 ARMY-NAVY DRIVE
ARLINGTON,VA 22202
ATTN ERNEST BAUER

INSTITUTE FOR DEFENSE ANALYSE
400 ARMY-NAVY DRIVE
ARLINGTON VA 22202
ATTN HANS WOLFHARD

MISSION RESEARCH CORPORATION
735 STATE STREET
SANTA BARBARA,CA 93101
ATTN D ARCHER

MISSION RESEARCH CORPORATION
735 STATE STREET
SANTA BARBARA,CA 93101
ATTN D FISCHER

MISSION RESEARCH CORPORATION
735 STATE STREET
SANTA BARBARA,CA 93101
ATTN M SCHEIBE

MISSION RESEARCH CORPORATION
735 STATE STREET
SANTA BARBARA,CA 93101
ATTN D SAPPENFIELD

MISSION RESEARCH CORPORATION
735 STATE STREET
SANTA BARBARA,CA 93101
ATTN D SOWLE

PHOTOMETRIC, INC.
442 MARRETT ROAD
LEXINGTON,MA 02173
ATTN IRVING L KOFSKY

PHYSICAL DYNAMICS INC.
P.O. BOX 1069
BERKELEY,CA 94701
ATTN J B WORKMAN

PHYSICAL DYNAMICS INC.
P.O. BOX 1069
BERKELEY,CA 94701
ATTN A THOMPSON

PITTSBURGH, UNIVERSITY OF
OF THE COMWLTH SYS OF HIGHER EDUC
CATHEDRAL OF LEARNING
PITTSBURGH,PA 15213
ATTN MANFRED A BIONDI

PHYSICAL SCIENCES,INC.
30 COMMERCE WAY
WOBURN,MA 01801
ATTN KURT WRAY

PITTSBURGH, UNIVERSITY OF
OF THE COMWLTH SYS OF HIGHER EDUC
CATHEDRAL OF LEARNING
PITTSBURGH,PA 15213
ATTN FREDERICK KAUFMAN

PHYSICAL SCIENCES,INC.
30 COMMERCE WAY
WOBURN,MA 01801
ATTN R L TAYLOR

PITTSBURGH, UNIVERSITY OF
OF THE COMWLTH SYS OF HIGHER EDUC
CATHEDRAL OF LEARNING
PITTSBURGH,PA 15213
ATTN EDWARD GERJUOY

PHYSICAL SCIENCES,INC.
30 COMMERCE WAY
WOBURN,MA 01801
ATTN G CALEDONIA

PRINCETON UNIV, THE TRUSTEES OF
FORRESTAL CAMPUS LIBRARY
BOX 710
PRINCETON UNIVERSITY
PRINCETON,NJ 08540
ATTN ARNOLD J KELLY

PHYSICS INTERNATIONAL COMPANY
2700 MERCED STREET
SAN LEANDRO,CA 94577
ATTN DOC CON FOR TECH LIB

R & D ASSOCIATES
P.O. BOX 9695
MARINA DEL REY,CA 90291
ATTN RICHARD LATTER

PITTSBURGH, UNIVERSITY OF
OF THE COMWLTH SYS OF HIGHER EDUC
CATHEDRAL OF LEARNING
PITTSBURGH,PA 15213
ATTN WADE L FITE

R & D ASSOCIATES
P.O. BOX 9695
MARINA DEL REY,CA 90291
ATTN R G LINDGREN

R & D ASSOCIATES
P.O. BOX 9695
MARINA DEL REY,CA 90291
ATTN BRYAN GABBARD

R & D ASSOCIATES
P.O. BOX 9695
MARINA DEL REY,CA 90291
ATTN D DEE

R & D ASSOCIATES
P.O. BOX 9695
MARINA DEL REY,CA 90291
ATTN H A DRY

R & D ASSOCIATES
1815 N. FT. MYER DRIVE
11TH FLOOR
ARLINGTON,VA 22209
ATTN HERBERT J MITCHELL

R & D ASSOCIATES
P.O. BOX 9695
MARINA DEL REY,CA 90291
ATTN ROBERT E LELEVIER

R & D ASSOCIATES
1815 N. FT. MYER DRIVE
11TH FLOOR
ARLINGTON,VA 22209
ATTN J W ROSENGREN

R & D ASSOCIATES
P.O. BOX 9695
MARINA DEL REY,CA 90291
ATTN R P TURCO

RAND CORPORATION
1700 MAIN STREET
SANTA MONICA,CA 90406
ATTN CULLEN CRAIN

R & D ASSOCIATES
P.O. BOX 9695
MARINA DEL REY,CA 90291
ATTN ALBERT L LATTER

SCIENCE APPLICATIONS, INC.
P.O. BOX 2351
LA JOLLA,CA 92038
ATTN DANIEL A HAMLIN

R & D ASSOCIATES
P.O. BOX 9695
MARINA DEL REY,CA 90291
ATTN FORREST GILMORE

SCIENCE APPLICATIONS, INC.
P.O. BOX 2351
LA JOLLA, CA 92038
ATTN DAVID SACHS

SPACE DATA CORPORATION
1331 SOUTH 26TH STREET
PHOENIX,AZ 85034
ATTN EDWARD F ALLEN

STANFORD RSCH INSTITUTE INTERNATIONAL
333 RAVENSWOOD AVENUE
MENLO PARK, CA 94025
ATTN M BARON

STANFORD RSCH INSTITUTE INTERNATIONAL
333 RAVENSWOOD AVENUE
MENLO PARK, CA 94025
ATTN L LEADABRAND

STANFORD RSCH INSTITUTE INTERNATIONAL
333 RAVENSWOOD AVENUE
MENLO PARK, CA 94025
ATTN WALTER G CHESTNUT

STANFORD RSCH INSTITUTE INTERNATIONAL
1611 NORTH KENT STREET
ARLINGTON,VA 22209
ATTN WARREN W BERNING

STANFORD RSCH INSTITUTE INTERNATIONAL
1611 NORTH KENT STREET
ARLINGTON,VA 22209
ATTN CHARLES HULBERT

TECHNOLOGY INTERNATIONAL CORPORATION
75 WIGGINS AVENUE
BEDFORD,MA 01730
ATTN W P BOQUIST

UNITED TECHNOLOGIES CORPORATION
755 MAIN STREET
HARTFORD,CT 06103
ATTN H MICHELS

UNITED TECHNOLOGIES CORPORATION
755 MAIN STREET
HARTFORD,CT 06103
ATTN ROBERT HBULLIS

UTAH STATE UNIVERSITY
LOGAN, UT 84321
ATTN DORAN BAKER

UTAH STATE UNIVERSITY
LOGAN, UT 84321
ATTN KAY BAKER

UTAH STATE UNIVERSITY
LOGAN, UT 84321
ATTN C WYATT

UTAH STATE UNIVERSITY
LOGAN, UT 84321
ATTN D BURT

VISIDYNE,INC.
19 THIRD AVENUE
NORTHWEST INDUSTRIAL PARK
BURLINGTON,MA 01803
ATTN HENRY J SMITH

VISIDYNE,INC.
19 THIRD AVENUE
NORTHWEST INDUSTRIAL PARK
BURLINGTON,MA 01803
ATTN J W CARPENTER

VISIDYNE,INC.
19 THIRD AVENUE
NORTHWEST INDUSTRIAL PARK
BURLINGTON,MA 01803
ATTN WILLIAM REIDY

19 THIRD AVENUE
NORTHWEST INDUSTRIAL PARK
BURLINGTON,MA 01803
ATTN T C DEGGES

VISIDYNE,INC.
19 THIRD AVENUE
NORTHWEST INDUSTRIAL PARK
BURLINGTON,MA 01803
ATTN CHARLES HUMPHREY

WAYNE STATE UNIVERSITY
1064 MACKENZIE HALL
DETROIT, MI 48202
ATTN PIETER K ROL CHAM ENGRG & MAT SCI

WAYNE STATE UNIVERSITY
1064 MACKENZIE HALL
DETROIT, MI 48202
ATTN R H KUMMLER

WAYNE STATE UNIVERSITY
~~DEPT. OF PHYSICS~~
DETROIT, MI 48202
ATTN WALTER E KAUPPILA

YALE UNIVERSITY
NEW HAVEN, CT 06520
ATTN ENGINEERING DEPARTMENT